Spray Drift Deposition of Dicamba Using a Hooded Sprayer

Report:	MRID 51242201. Beachum, C.E. 2019. Spray Drift Deposition of Solutions Containing Dicamba formulation MON 54140 Using Different Application Technologies. Final Report. Unpublished study performed by Monsanto Company, Chesterfield, Missouri; Analytical Bio-Chemistry Laboratories, Inc., Columbia, Missouri; Stone Environmental, Inc., Montpelier, Vermont; and Batelle, Norwell, Massachusetts; and sponsored by Monsanto Company, Chesterfield, Missouri. Report & Task No.: REG-2017-0465, MSL0029261. Study initiation August 15, 2017 and completion May 15, 2019 (p. 8). Final report issued May 15, 2019.
Document No.:	MRID 51242201
Guideline:	840.1200
Statements:	The study was conducted in accordance with EPA Good Laboratory Practice Standards, except for test site information, study weather data, pesticide and crop history information, and test plot preparation prior to application (p. 3). Signed and dated Data Confidentiality, GLP, Quality Assurance, and Certificate of Authenticity Statements were provided (p. 2-5).
Classification:	This study is classified **supplemental**. Treated fields were fallow fields (bare ground or stubble less than 7.5 cm [2.95 in] in height) which may not be reflective of an application to soybean/cotton plants. Samples were analyzed between 145 and 148 days after sample collection which was after the demonstrated stability period for dicamba of 85 days on filter paper. The Limit of Detection (LOD) for the analytical method was not reported.
PC Code:	128931

Final EPA Reviewer:	Chuck Peck Senior Fate Scientist	Signature: Date:	Chuck Peck 2020.10.22 13:59:09 -04'00'
Final EPA Reviewer:	William P. Eckel, Ph.D. Senior Advisor	Signature: Date:	William P. Eckel Digitally signed by William P. Eckel Date: 2020.10.23 10:46:31 -04'00'

Executive Summary

A field deposition study was conducted in August 2017 in Lubbock County, Texas to measure deposition following spray applications of a dicamba formulation at a rate of 1.12 kg a.e./ha (1.0 lb a.e./A) using different application technologies and under varying environmental conditions. A spray solution of MON 54140 containing 0.25% v/v Induce® non-ionic surfactant was applied with three different types of spray nozzles using two different application methods at two different wind speed ranges in the presence and absence of the drift reduction adjuvant Intact® (0.5% v/v). The three types of nozzles used were: Turbo TeeJet® Induction flat spray tip (TTI), Air Induction Extended Range TeeJet® flat spray tip (AIXR), and Turbo TeeJet® wide angle flat spray tip (TT). Nozzle orifice size for each application method was selected to give the desired application rate of 16 – 17 gal/A (150 -159 L/ha) based on the travel speed for each application method.

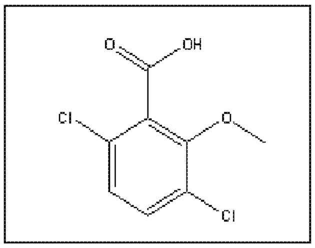
The two application methods were the Wilmar Fabrication LLC Redball® 642E hooded sprayer and an open boom sprayer equipped with the K-B Agritech, LLC Pattern Master. The targeted wind speed ranges during application were either less than 10 mph (4.5 m/sec) or greater than or equal to 10 mph (4.5 m/sec). For the Redball® 642E hooded sprayer, the application area for each tank mix/nozzle/wind speed range combination (i.e. treatment) consisted of 4 spray swaths each 240 m (787 ft) long and 12.2 m (40 ft) wide for a total spray area width of 48.8 m (160 ft) and the application speed was approximately 6 mph. For the open boom sprayer equipped with Pattern Master technology, the application area for each tank mix/nozzle/wind speed range combination consisted of two spray swaths, each 240 m (787 ft) long and 27.4 m (90 ft) wide for a total spray area width of 54.9 m (180 ft) and the application speed was approximately 10 mph. For all treatments, regardless of application method, spray drift deposition collectors were located along three parallel transects at 4, 8, 16, 30.5, 45, 60, 75, 90, 105, and 120-m downwind of the edge of the application area. Due to time, weather conditions, and treatment priorities, the Pattern Master treatments 8, 11, 17, and 18 were not conducted.

Study authors estimated spray drift curves for the various treatments using a 4-parameter, exponential decay model. The reviewer used the modified Morgan-Mercer-Floden function, the same equation used in modeling ground applications in the AgDRIFT model, to model the spray drift deposition. **Table 1** presents spray drift parameters for the drift curves for the various replicates based on the deposition data and the distance to the nontarget plant no observable effect rate (2.61×10^{-4} lb a.e./A). It should be noted that the reviewer distances are based on 20 swaths while the study authors' distances are based on the swaths used on the treatments.

Table 1. Summary of spray drift parameters for dicamba spray drift trials

Treatment	Drift Reduction Technology	Nozzle	Wind speed (mph)	a (m^{-1})	b (unitless)	Reviewer Distance to Effect (m)[1]	Study Distance to Effect (m)
1	Hooded sprayer	TTI 11003	11.9	5788	1.0544	< 4	< 4
2	Hooded sprayer	TT 11003	17.4	36.989	1.5796	< 4	6.7
3	Hooded sprayer	AIXR 11003	12.3	138.04	1.3779	< 4	3.4
4[2]	Hooded sprayer	TTI 11003	10.4	53403	0.9032	< 4	< 4
5[2]	Hooded sprayer	TT 11003	11	1211	1.0825	< 4	0
6[2]	Hooded sprayer	AIXR 11003	10.1	301.44	1.2774	< 4	0
7	Pattern Master	TTI 11005	8.4	5.7163	1.7114	32	20.1
9	Pattern Master	AIXR 11005	10.2	18.741	1.3125	82	39
10[2]	Pattern Master	TTI 11005	11.7	24.609	1.4725	14.5	14.6
12[2]	Pattern Master	AIXR 11005	12.4	12.887	1.3519	105	31.4
13[2]	Hooded sprayer	TTI 11003	8.5	21572	0.9949	< 4	< 4
14[2]	Hooded sprayer	TT 11003	5.0	2133	1.1308	< 4	< 4
15[2]	Hooded sprayer	AIXR 11003	9.4	848.60	1.1589	< 4	0.7
16[2]	Pattern Master	TTI 11005	7.7	3.7407	2.1264	13.8	11.3
19	Hooded sprayer	TTI 11003	7.4	392.7	1.3363	< 4	< 4
20	Hooded sprayer	TT 11003	6.5	643.95	1.2017	< 4	2.5
21	Hooded sprayer	AIXR 11003	7.6	2893	1.0494	< 4	0
22	Pattern Master	TTI 11005	8.1	3.2375	2.0481	19.6	17.4
23	Pattern Master	TT 11005	5.3	14.316	1.3900	64	38.1
24	Pattern Master	AIXR 11005	9.1	5.0651	1.6179	62	38.1

1. Reviewer estimated distances account for 20 swaths for the hooded sprayer and 10 swaths for the Pattern Master, standard practice for EFED in using the AgDRIFT model. Study authors determined distance to effects based on the number of swaths run in the study.
2. Tank mix included Intact, a drift reducing agent



I. Materials and Methods

A. Materials

1. Test Material:

1. Test Material: Product Name: MON 54140 (Clarity)
(diglycolamine salt of dicamba, p. 15)
Formulation Type: Liquid (478 g/L; 39.2% w/w; p. 696)
Lot Number: 11478408
CAS #: 104040-79-1
Storage stability: The expiration date of the test substance was August 14, 2018.

Product Name: Induce
Formulation type: Liquid
Batch Number: WA6J057GHS
Storage stability: The expiration date of the test substance was May 8, 2022.

Product Name: Intact
Formulation type: Liquid
Batch Number: 374-25
Storage stability: The expiration date of the test substance was May 8, 2022.

Storage stability: Test substances were stored at the sponsor's facility near the test site in Shallowater, Texas. Storage facility temperature was monitored beginning on August 2, 2017 using a wireless Hobo MX1101 logger (p. 75).

2. Storage Conditions

Storage temperatures and conditions were not provided.

B. Study Design

1. Site Description

The test sites were located in Lubbock County, Texas, in a primarily agricultural area northwest of Shallowater, Texas which is a location that is representative of intended use areas for the commercial formulation that was evaluated in this study. Two different agricultural field sites were used for test substance applications. The first site was located approximately 3.7 mi (~ 6 km) northwest of Shallowater and was bordered by U.S. Route 84 on its southwestern edge and by FM 179 on its eastern edge. The second test site was approximately 10.5 mi (~ 17 km) north of Shallowater and was bordered on its northern edge by FM597 and on its eastern edge by FM179. Four fields, approximately 240 m x 49 m (2.89 A), were used at the first site for spray drift testing of the Redball® hooded sprayer, while two fields, approximately 240 m x 55 m (3.26 A), were used at the first site for spray drift testing of the Pattern Master. Three fields, approximately 240 m x 49 m, were used at the second site for spray drift testing of the Redball® hooded sprayer, while three fields, approximately 240 m x 55 m, were used at the second site for spray drift testing of the Pattern Master. Treated fields were fallow fields (bare ground or stubble less than 7.5 cm [2.95 in] in height).

2. Application Details

Application rate(s):	The target dicamba application rate was 1.0 lb a.e./A (1.12 kg a.e./ha; p. 14). Four filter paper samples were located within each spray swath for each application, for a total of 16 in swath samples, to measure the actual application rate (pp. 27-28).
Irrigation and Water Seal(s):	No irrigation water was used.
Tarp Applications:	Tarps were not used
Application Equipment:	The Wilmar Fabrication LLC Redball® hooded sprayer system consisted of a three-point broadcast hood mounted along a 12.2 m (40 ft) specialized boom arm containing 24 nozzles at a 20 in spacing and connected to a 300-gallon tank and a specialized spray system. Three different sets of nozzles were used: Turbo TeeJet Induction (TTI) 11003, Turbo TeeJet (TT) 11003, and Air Induction Extended Range (AIXR) 11003. Due to the spray angle of the nozzles, the TTI and TT nozzles required a mounting bracket for the three-option nozzle body to prevent spraying directly into the hood. The AIXR nozzles did not require the mounting bracket. For this reason, two different hooded sprayers were used for the treatments – one pulled by a John Deere 8120 tractor for the TTI11003 and TT11003 nozzles and one pulled by a Case 125 tractor for the AIXR11003 nozzles. Both sprayers were driven to maintain a constant speed targeted at approximately 6 mph (p. 19). Boom height was set to approximately 20 in (50.8 cm) above the ground surface and was checked periodically for both sprayers used in the study (p. 25). The K-B Agritech, LLC Pattern Master consisted of aluminum shields and polyethylene brushes mounted along the boom arm in front of the spray nozzles. The Pattern Master shields and brushes were installed on the 27.4 m (90 ft) boom arm of a John Deere 4720 ground sprayer prior to the experimental start date. Three different nozzle types were tested: TTI 11005, AIXR 11005, and TT 11005. Nozzles were spaced every 20 inches on the boom for a total of 53 nozzles. The sprayer was driven to maintain a constant speed targeted at approximately 10 mph (p. 19-20). Boom height was set to approximately 20 in (50.8 cm) above the ground surface and was checked periodically (p. 26).

Equipment Calibration Procedures:	All individual nozzles of each nozzle type were tested three times to determine variability between tests and nozzles. Each individual nozzle was tested by measuring the rate that liquid was collected in SpotOn® Sprayer Calibrator devices (Model: SC-1). Verification of all three types of nozzles was conducted by spraying at 3.45 bar (50 psi), the pressure appropriate for the nozzle to achieve the desired spray quality (p. 22-23).
Application Regime:	The application rates and nozzles used for each application pass are summarized in **Table 2**.

Table 2. Summary of application and rates for dicamba

Tmt	DRT	Nozzle	Date/time of application	Target Application Rate			Measured GPA	Percent of Target Rate
				lbs a.e./A	g a.e./ha	GPA		
1	HS	TTI 11003	8/28/17, 15:41-15:49	1.0	1120	16.6	16.51	99.5
2	HS	TT 11003	8/28/17, 14:38-14:41	1.0	1120	16.6	17.10	103
3	HS	AIXR 11003	8/25/17, 19:04-19:13	1.0	1120	16.8	16.53	98.4
4	HS	TTI 11003	8/29/17, 14:36-14:44	1.0	1120	16.6	16.78	101
5	HS	TT 11003	8/29/17, 15:25-15:55	1.0	1120	16.6	17.03	103
6	HS	AIXR 11003	8/26/17, 18:16-18:24	1.0	1120	16.8	16.46	97.95
7	PM	TTI 11005	8/29/17, 17:44-17:48	1.0	1120	16.6	16.81	101
9	PM	AIXR 11005	8/29/17, 18:23-18:24	1.0	1120	16.6	16.79	101
10	PM	TTI 11005	8/29/17, 16:33-16:35	1.0	1120	16.6	16.18	97.5
12	PM	AIXR 11005	8/29/17, 13:45-13:52	1.0	1120	16.6	16.62	100
13	HS	TTI 11003	8/25/17, 16:31-16:38	1.0	1120	16.6	16.93	102
14	HS	TT 11003	8/25/17, 17:21-17:29	1.0	1120	16.6	16.79	101
15	HS	AIXR 11003	8/25/17, 19:53-20:01	1.0	1120	16.8	16.49	98.1
16	PM	TTI 11005	8/29/17, 13:04-13:07	1.0	1120	16.6	17.05	103
19	HS	TTI 11003	8/25/17, 15:17-15:25	1.0	1120	16.6	17.02	103
20	HS	TT 11003	8/25/17, 14:14-14:22	1.0	1120	16.6	16.61	100
21	HS	AIXR 11003	8/26/17, 17:28-17:36	1.0	1120	16.8	16.56	98.5
22	PM	TTI 11005	8/26/17, 16:05-16:07	1.0	1120	16.6	16.89	102
23	PM	TT 11005	8/27/17, 15:02-15:06	1.0	1120	16.5	16.92	103
24	PM	AIXR 11005	8/26/17, 16:36-16:38	1.0	1120	16.6	16.88	102

Data obtained from Tables 4a and 4b, p. 46-49.

Approximately five minutes after each application, filter paper samples were collected from the field, placed in conical tube containers that were capped and placed in a labelled box until all samples were collected. Samples were then stored in coolers containing dry ice and stored in a secure location prior to shipment (pp. 27-28).

3. Soil Properties

Not reported.

4. Meteorological Sampling

Prior to spray applications, the main weather station was assembled on a ~3.7 m (12 ft) long flat-bed trailer for mobility and was moved among the test plots using a John Deer Gator utility vehicle. Wind speed and direction data was gathered using a Gill WindMaster (Part 1590-PK-020) three-dimensional (3D) sonic anemometer that was fixed to the main weather station at a height of ~2 m above the ground to collect high resolution wind data before, during, and after all test substance applications. The Gill anemometer recorded both vertical and horizontal wind speed and direction data at a one-second interval. Prior to each test substance application, the weather station was positioned at an upwind location within 30 m of the application area. Wind speed and direction data gathered by the Gill 3D anemometer was monitored using an HP laptop computer by the Field Research Principal Investigator in real time before, during, and after each application to inform when spray applications should occur. Other meteorological instruments included a temperature/relative humidity sensor and a solar radiation pyranometer, which recorded data at a one-minute interval. These other weather station sensors were connected to an Onset Computer Corporation Hobo® Weather Station (H21-001) data logger.

In addition to the main weather station, wind speed and direction data were gathered ~4 m downwind of the application area using a Davis cup anemometer placed at boom height (~20 in). The boom height anemometer monitored and recorded wind at a 1-min interval and was connected to an Onset Computer Corporation HOBO® Microstation data logger. This instrument provided additional information on wind speed and direction at the release height of the spray. Wind data from the Gill 3D anemometer were used to determine when wind speeds were within the target wind speed ranges for each study treatment.

Table 3 summarizes the meteorological conditions during spraying for each treatment. Wind direction during treatment was within 30° except for Treatment 2, a hooded sprayer application using TT 11003 nozzles, where the deviation of the wind direction was 30.1° from the target.

Table 3. Meteorological conditions during application

Tmt	DRT	Nozzle	Date/time of application	Air temperature (°F)	Relative humidity (%)	Maximum wind speed (mph)	Wind direction (°)
1	HS	TTI 11003	8/28/17, 15:41-15:49	82.3	58	11.9	95
2	HS	TT 11003	8/28/17, 14:38-14:41	80	57	17.4	75
3	HS	AIXR 11003	8/25/17, 19:04-19:13	77.8	70	12.3	101
4	HS	TTI 11003	8/29/17, 14:36-14:44	83.6	36	10.4	25
5	HS	TT 11003	8/29/17, 15:25-15:55	84.6	35	11.0	34
6	HS	AIXR 11003	8/26/17, 18:16-18:24	80.1	64	10.1	95
7	PM	TTI 11005	8/29/17, 17:44-17:48	84.5	34	8.4	31
9	PM	AIXR 11005	8/29/17, 18:23-18:24	82.8	35	10.2	36
10	PM	TTI 11005	8/29/17, 16:33-16:35	84.9	35	11.7	60
12	PM	AIXR 11005	8/29/17, 13:45-13:52	82.6	38	12.4	62
13	HS	TTI 11003	8/25/17, 16:31-16:38	87.1	47	8.5	70
14	HS	TT 11003	8/25/17, 17:21-17:29	82.8	52	5.0	91
15	HS	AIXR 11003	8/25/17, 19:53-20:01	72.8	70	9.4	116
16	PM	TTI 11005	8/29/17, 13:04-13:07	83.3	34	7.7	54
19	HS	TTI 11003	8/25/17, 15:17-15:25	86.5	44	7.4	78
20	HS	TT 11003	8/25/17, 14:14-14:22	84.3	52	6.5	111
21	HS	AIXR 11003	8/26/17, 17:28-17:36	78.6	72	7.6	69
22	PM	TTI 11005	8/26/17, 16:05-16:07	82.5	61	8.1	88
23	PM	TT 11005	8/27/17, 15:02-15:06	85.4	48	5.3	55
24	PM	AIXR 11005	8/26/17, 16:36-16:38	83.7	59	9.1	80

Data obtained from Appendix 1A, Tables 3-5, p. 90-96 and Appendix 1B, Tables 3-5, p. 307-311.

5. Deposition Capture

Drift deposition collectors were round 125-mm Whatman filter paper affixed to a 6 in by 6 in piece of cardboard that was affixed to a 5.5 in x 6 in pinewood board. The filter paper collector was held in place with three or four small dressmaker's pins driven through the filter paper and into the cardboard. The collectors were placed in three parallel lines 15 meters apart at distances of 4, 8, 16, 30.5, 45, 60, 75, 90, 105, and 120 meters downwind from the edge of the treated field (pp. 26).

Three upwind samples were collected for each treatment from sampling stations located along each transect at 79 m (hooded sprayer) or 85 m (Pattern Master technology) upwind of the edge-of-field line (approximately 30 m upwind of the application area). These samples were collected by the Principal Field Investigator who did not enter the application area or downwind deposition areas during the study (p. 27).

Spray area stations were prepared similarly to the deposition stations but were long enough to accommodate four filter papers per board (5.5 in x 24 in) and were located within the path of the sprayer. Spray area samples were collected at four locations within each study treatment along a line that was an extension of the middle sample transect line into the application area. At each of the four locations, four filter papers were collected, for a total of 16 in-swath samples for each study treatment. To limit cross-contamination, these samples were collected by personnel who were not collecting downwind or upwind samples during the study (p. 27-28).

6. Tank Mix and Transit Stability Samples

Tank mix samples were collected prior to each application and after each application for all treatments. Three replicate samples of at least 30 mL each were collected in uniquely labeled vials before and after application for all 20 treatments. A dip sampler was used to collect the tank mix samples (p. 28).

Transit stability samples were generated but were not analyzed because analytical results of the downwind deposition samples did not indicate circumstances that would question sample stability during transportation (p. 28).

7. Sample Handling and Storage Stability

After each spray application, five minutes were allowed to elapse, then the filter paper collectors were collected (pp. 27). Filter papers were placed into conical tube containers, capped and place in a labelled box until all samples were collected. The samples were then placed in coolers with dry ice and stored in a secure location prior to shipment.

Samples from the study site were packed by the field staff and shipped on dry ice (filter paper samples) or under ambient conditions (tank mix samples) by FedEx to the analytical laboratory. Upwind and downwind deposition samples and transit stability samples were later packed by personnel and shipped on dry ice by FedEx to the analytical laboratory (p. 28).

8. Analysis of Deposition Data

The mass of dicamba present on each collector was determined analytically, and study authors described the spray drift of dicamba using a 4-parameter, exponential decay model to capture the biphasic deposition pattern (p. 617).

9. Analytical Methodology

Analysis of tank mix and in-swath samples was performed by the analytical laboratory. Tank mix spray solution samples were shipped under ambient conditions, and in-swath samples are assumed to have been received frozen because the analytical laboratory receiving records indicate temperatures from -22.3°C - -21.9°C and no protocol deviations were noted (p. 29). Tank mix samples were analyzed by HPLC according to method ME-1679-01 to determine the concentration of dicamba in tank mix samples. Although method ME-1679-01 is for a different formulation, the method was considered acceptable for other dicamba containing formulations. The method employed liquid chromatography on a C18 column with gradient elution using acetonitrile and 0.1 M phosphoric acid mobile phases, with UV detection at 280nm. Standard curves for sample analyses were generated from standard solutions corresponding in concentrations from 0.001 to 0.026 wt % dicamba.

In-swath samples were analyzed for by HPLC according to method ME-1929-01 to determine the concentration of dicamba in the application area. The method employs liquid chromatography on a C18 column with gradient elution using acetonitrile and 0.1 M phosphoric acid mobile phases, with UV detection at 280nm. Standard curves for sample analyses were generated from standard solutions corresponding in concentrations from 0.0001 to 0.02 wt % dicamba. A representative calibration curve had an R2 value of 0.999971. Samples were analyzed between 145 and 148 days after sample collection. Analysis of samples was conducted after the demonstrated stability period for dicamba of 85 days on filter paper resulting in an analytical deviation. Study authors indicated the deviation had no effect on the study because analysis of the in-swath samples resulted in recoveries within the expected range.

The level of quantitation (LOQ) was 0.005 μg/filter (p. 30). The level of detection (LOD) was not reported. No independent method validation is reported.

10. Quality Control

Lab Recovery:	All procedural recoveries at all fortification levels were within the acceptable range between 70 and 120% with a RSD of less than 20% (p. 487). The mean procedural overall recovery result for filter paper analyses (n = 84) was 102% ± 4.84%. Filter paper fortification levels were 0.005, 5.0, and 50.0 μg/filter.
Upwind Control:	Trace level detections of dicamba ranging from 3.9×10^{-6} lb a.e./A to 8.4×10^{-6} lb a.e./A were found in some upwind control samples (p. 37). These trace levels did not significantly impact the accuracy of the quantitation of residues in treated samples.

II. Results and Discussion

A. Deposition of Dicamba

Table 4 and **Table 5** summarize the analytical results for spray drift observed on filter paper samples for the hooded sprayer and Pattern Master treatments, respectively.

Table 4. Analytical results summary of hooded sprayer samples

Substrate/ Nozzle	Distance (m)	Deposition (µg/filter)			
		Treatment 1	**Treatment 4**	**Treatment 13**	**Treatment 19**
TTI 11003	4	0.03583 - 0.04451	0.01997 - 0.03098	0.01208 - 0.02291	0.04547 - 0.15851
	8	0.01722 - 0.04009	0.01401 - 0.01504	0.01134 - 0.01643	0.03479 - 0.051
	16	0.00927 - 0.01637	0.00792 - 0.01995	0.00905 - 0.01071	0.0241 - 0.02448
	31	0.00839 - 0.02704	0.00674 - 0.01044	0.00532 - 0.01427	0.01446 - 0.01607
	45	0.00673 - 0.01377	0.01287 - 0.01773	0.00693 - 0.02193	0.00646 - 0.01544
	60	0.00553 - 0.01283	0.00507 - 0.00736	ND	0.00533 - 0.01089
	75	0.00674 - 0.00674	0.00538 - 0.01489	ND	0.00635 - 0.01003
	90	0.00585 - 0.00906	0.00603 - 0.00603	ND	ND
	105	ND - 0.00632	ND	ND	ND
	120	ND - 0.00592	ND - 0.0059	ND	ND
	Upwind	ND	ND - 0.01155	ND	ND
		Treatment 2	**Treatment 5**	**Treatment 14**	**Treatment 20**
TT 11003	4	0.31551 - 1.98503	0.11318 - 0.31429	0.05527 - 0.08351	0.16069 - 0.37844
	8	0.12045 - 0.3186	0.0806 - 0.09383	0.01956 - 0.0445	0.06593 - 0.07772
	16	0.07205 - 0.12902	0.04508 - 0.0972	0.01305 - 0.02735	0.02792 - 0.05232
	31	0.01821 - 0.07291	0.01836 - 0.05145	0.01175 - 0.02056	0.00787 - 0.0225
	45	0.02115 - 0.04196	0.01607 - 0.0872	0.00808 - 0.01555	0.0085 - 0.02059
	60	0.01192 - 0.03981	0.03651 - 0.04074	0.00623 - 0.01779	0.01105 - 0.0235
	75	0.00702 - 0.02273	0.01716 - 0.03217	0.00613 - 0.00938	0.00804 - 0.01486
	90	0.00811 - 0.01977	0.01087 - 0.02095	0.00514 - 0.0071	0.01129 - 0.01224
	105	0.01065 - 0.0156	0.00825 - 0.01005	ND	0.00756 - 0.01595
	120	0.01284 - 0.01787	0.00971 - 0.01493	ND	0.00567 - 0.01071
	Upwind	0.00533 - 0.00863	ND	ND	ND
		Treatment 3	**Treatment 6**	**Treatment 15**	**Treatment 21**
AIXR 11003	4	0.25399 - 0.50464	0.1221 - 0.27416	0.1171 - 0.27808	0.1089 - 0.13352
	8	0.07862 - 0.13122	0.05534 - 0.09134	0.06149 - 0.07622	0.0645 - 0.08725
	16	0.04323 - 0.07101	0.05212 - 0.06499	0.03016 - 0.04354	0.01631 - 0.03775
	31	0.03274 - 0.06729	0.03918 - 0.05686	0.02297 - 0.04	0.01365 - 0.03362
	45	0.01444 - 0.04792	0.01042 - 0.03793	0.0142 - 0.03789	0.01325 - 0.01678
	60	0.01301 - 0.02608	0.01004 - 0.03774	0.01704 - 0.02444	0.0102 - 0.01465
	75	0.01027 - 0.01684	0.00881 - 0.01826	0.01646 - 0.02061	0.01142 - 0.01944
	90	0.00745 - 0.01193	0.00893 - 0.01168	0.00693 - 0.01553	0.00633 - 0.00936
	105	0.01055 - 0.01533	0.01031 - 0.01786	0.00922 - 0.01234	0.01254 - 0.01441
	120	0.00833 - 0.01187	0.01001 - 0.01001	0.01215 - 0.01215	0.00829 - 0.01628
	Upwind	ND	ND	ND	ND

ND = 0.005 µg/sample

Table 5. Analytical results summary of Pattern Master samples

Substrate/ Nozzle	Distance (m)	Deposition (µg/filter)			
		Treatment 7	**Treatment 10**	**Treatment 16**	**Treatment 22**
TTI 11005	4	6.8163 - 16.3747	0.87239 - 4.17667	2.22425 - 9.2639	4.0519 - 6.5863
	8	1.02892 - 3.75972	0.35472 - 2.00125	0.63855 - 1.63881	1.11916 - 3.19676
	16	0.19573 - 0.85441	0.08335 - 0.55136	0.18919 - 0.49439	0.51463 - 0.93268
	31	0.12119 - 0.34632	0.08008 - 0.21481	0.03529 - 0.05998	0.0856 - 0.20646
	45	0.09384 - 0.15145	0.04095 - 0.19625	0.01678 - 0.04715	0.05348 - 0.08532
	60	0.08833 - 0.13003	0.04056 - 0.17985	0.01891 - 0.05662	0.03078 - 0.08233
	75	0.02138 - 0.0748	0.01137 - 0.04819	0.00606 - 0.01877	0.01138 - 0.03092
	90	0.0459 - 0.08674	0.02617 - 0.03394	0.00643 - 0.01287	0.0128 - 0.02519
	105	0.03001 - 0.06273	0.0194 - 0.03072	0.00635 - 0.00877	0.01028 - 0.03253
	120	0.05306 - 0.12134	0.01728 - 0.02994	0.00648 - 0.00968	ND
	Upwind	ND	ND	ND - 0.00679	ND - 0.00676
		Treatment 23			
TT 11005	4	4.35197 - 10.7637	NA	NA	NA
	8	1.39202 - 2.48608	NA	NA	NA
	16	0.55725 - 1.15188	NA	NA	NA
	31	0.28075 - 0.70278	NA	NA	NA
	45	0.12479 - 0.46131	NA	NA	NA
	60	0.18692 - 0.34591	NA	NA	NA
	75	0.09867 - 0.20865	NA	NA	NA
	90	0.08732 - 0.17017	NA	NA	NA
	105	0.07723 - 0.13345	NA	NA	NA
	120	0.05475 - 0.08656	NA	NA	NA
	Upwind	ND	NA	NA	NA
		Treatment 9	**Treatment 12**	**Treatment 24**	
AIXR 11005	4	1.14842 - 13.8002	7.754 - 10.3842	6.00772 - 14.7086	NA
	8	1.28939 - 3.24868	2.19548 - 5.53241	2.31293 - 6.2897	NA
	16	0.58861 - 1.11008	0.9639 - 1.6034	1.40513 - 1.69553	NA
	31	0.37639 - 0.71662	0.26549 - 0.43772	0.50289 - 0.77661	NA
	45	0.29485 - 0.44038	0.15006 - 0.47524	0.24485 - 0.30751	NA
	60	0.14669 - 0.20678	0.15427 - 0.25827	0.12452 - 0.21881	NA
	75	0.10808 - 0.17346	0.09481 - 0.34271	0.15552 - 0.19037	NA
	90	0.11595 - 0.19959	0.16996 - 0.34254	0.10441 - 0.13308	NA
	105	0.09806 - 0.18146	0.15232 - 0.2392	0.0593 - 0.10849	NA
	120	0.07165 - 0.1515	0.09396 - 0.21793	ND	NA
	Upwind	ND	ND	ND - 0.00653	NA

ND = 0.005 µg/sample

Study authors determined that the downwind deposition pattern of dicamba in the MON 54140 tank mixes fit an exponential decay model for the hooded sprayer treatments (Treatments 2, 3, 5, 6, 15, 20 and 21). All treatments with the TTI nozzle (Treatments 1, 4, 13, and 19) and the treatment with the TT nozzle in the low wind speed range with DRA added (Treatment 14) did not fit either a biphasic decline or an exponential decay model; however, for each of these treatments all downwind deposition samples, even at the collection station closest to the edge-of-field line (4 m), have measured dicamba values that are less than 50% of the vegetative vigor nontarget plant no observable effect rate ($2.61x10^{-4}$ lb a.e./A) indicating that a buffer of less than 4 m (14 ft) would be required.

Study authors determined that the downwind deposition pattern of dicamba in the MON 54140 tank mixes fit a biphasic decline model for the Pattern Mater treatments (Treatments 7, 9, 12, 23, and 24) with an initial steep decline followed by a more gradual decline. For Treatments 10, 16, and 22 the downwind deposition pattern fit an exponential decay model. Due to time, weather conditions, and treatment priorities, treatments 8, 11, 17, and 18 were not conducted. To estimate the buffer distance required to protect non-target plants from a 1.12 kg a.e./ha (1.0 lb a,e, /A) application, the distance to reach the NOER for soybean from the vegetative vigor study was calculated from the relevant deposition model equation. The largest estimated buffer distance for any nozzle type was less than 128 ft (39 m) at the 1.12 lg a.e./ha (1.0 lb a.e./A) application rate. Only the TTI and AIXR nozzles were evaluated at the high wind speed range. The buffer distance for the TTI nozzle treatment (66 ft [20 m]) was shorter than for the AIXR nozzle (128 ft [39 m]). Addition of the drift reduction agent Intact®, resulted in some reduction in the buffer distance for the both the TTI and AIXR nozzle types (48 ft [15 m] and 103 ft [31 m], respectively). Under low wind speed range conditions, the buffer distance was shorter for the TTI nozzle type (57 ft [17 m]) than for either the AIXR and TT nozzle types (125 ft [38 m] each). The AIXR and TT nozzle types had similar buffer distances in the absence of Intact® drift reduction agent, although the wind speed was lower for the TT nozzle type. The buffer distance for the TTI nozzle type was also reduced in the low wind speed range to 37 ft (11 m) by the addition of Intact® to the tank mix.

Study authors estimated the spray drift curves using a 4-parameter, exponential decay model. The resulting equation for the spray drift curve was:

$$Dicamba_i = a\left(e^{-b*Distance_i}\right) + c\left(e^{-d*Distance_i}\right) + \varepsilon_i$$

where the terms are:

- $Dicamba_i$ is the mean or 90th percentile deposition value at distance i
- a represents the deposition in the first phase at distance=0
- b represents the deposition decay rate for the first phase
- c represents the deposition in the second phase at distance=0
- d represents the deposition decay rate for the second phase
- ε_i is the residual variance

The reviewer used the modified Morgan-Mercer-Floden function, the same equation used in modeling ground applications in the AgDRIFT model, to model the spray drift deposition:

$$D = \sum_{i=0}^{n-1} \frac{1}{\left(1 + a(d + [i\ x\ SW])\right)^b}$$

where D is the unitless deposition fraction, n is the number of swaths, d is the distance away from the field, in meters, SW is the swath width, in meters, and a and b are derived parameters. For this study, the number of swaths per replicate was 4 for the hooded sprayer and 2 for the Pattern Master. The swath width was 12.2 m for the hooded sprayer and 27.4 m for the Pattern Master. The deposition fraction was determined as the ratio of the measured deposition amount (in lb a.e./A) divided by the application rate (1 lb a.e/A). **Table 6** presents spray drift parameters for the drift curves for the various replicates based on the deposition data, as well as a comparison of the distance to the no observable effects level for dicamba (2.61×10^{-4} lb a.e./A) based on the reviewer and study authors curves. It should be noted that the distance to effect generated by the reviewer is adjusted to allow for 20 swaths for the hooded sprayer and 10 swaths for the Pattern Master, based on modeling using the AgDRIFT model. Distances estimated by the study authors only account for the number of swaths employed in the study.

Table 6. Summary of spray drift parameters for dicamba spray drift trials

Treatment	Drift Reduction Technology	Nozzle	a (m^{-1})	b (unitless)	Reviewer Distance to Effect (m)[1]	Study Authors Distance to Effect (m)
1	Hooded sprayer	TTI 11003	5788	1.0544	< 4	< 4
2	Hooded sprayer	TT 11003	36.989	1.5796	< 4	6.7
3	Hooded sprayer	AIXR 11003	138.04	1.3779	< 4	3.4
4[2]	Hooded sprayer	TTI 11003	53403	0.9032	< 4	< 4
5[2]	Hooded sprayer	TT 11003	1211	1.0825	< 4	0
6[2]	Hooded sprayer	AIXR 11003	301.44	1.2774	< 4	0
7	Pattern Master	TTI 11005	5.7163	1.7114	32	20.1
9	Pattern Master	AIXR 11005	18.741	1.3125	82	39
10[2]	Pattern Master	TTI 11005	24.609	1.4725	14.5	14.6
12[2]	Pattern Master	AIXR 11005	12.887	1.3519	105	31.4
13[2]	Hooded sprayer	TTI 11003	21572	0.9949	< 4	< 4
14[2]	Hooded sprayer	TT 11003	2133	1.1308	< 4	< 4
15[2]	Hooded sprayer	AIXR 11003	848.60	1.1589	< 4	0.7
16[2]	Pattern Master	TTI 11005	3.7407	2.1264	13.8	11.3
19	Hooded sprayer	TTI 11003	392.7	1.3363	< 4	< 4
20	Hooded sprayer	TT 11003	643.95	1.2017	< 4	2.5
21	Hooded sprayer	AIXR 11003	2893	1.0494	< 4	0
22	Pattern Master	TTI 11005	3.2375	2.0481	19.6	17.4
23	Pattern Master	TT 11005	14.316	1.3900	64	38.1
24	Pattern Master	AIXR 11005	5.0651	1.6179	62	38.1

Deposition curves for the various spray drift trials are presented in **Attachment 1**.

III. Study Deficiencies and Reviewer's Comments

1. Treated fields were fallow fields (bare ground or stubble less than 7.5 cm [2.95 in] in height). According to the Generic Verification Protocol for Testing Pesticide Application Spray Drift Reduction Technologies, the surface vegetation height should be less than 7.5 cm absolute height for all vegetation surface heights in drift sampling areas. While this requirement was met, the application may not be reflective of an application to soybean/cotton plants.

2. The boom height for the hooded sprayer study was set to 20 inches above the ground. This is consistent with guidance provided in the operators manual that indicates "Obtain correct nozzle height. Adjust height of toolbar so nozzle is at correct height above target (crop or ground)". Based on the characterization of the hooded sprayer as a "20" broadcast hood", it is believed that the hooded sprayer was 20 inches in height, which indicates the bottom of the

hood was very close to the ground. As a result, it is not surprising that there was minimal spray drift observed in the trials.

3. It is uncertain if the nozzles used in the study are approved for use with dicamba products that allow for over-the-top applications to soybean and cotton. The websites that provide listings of approved nozzles was no longer accessible.

4. Transit stability samples were generated but were not analyzed because analytical results of the downwind deposition samples did not indicate circumstances that would question sample stability during transportation.

5. Samples were analyzed between 145 and 148 days after sample collection. Analysis of samples was conducted after the demonstrated stability period for dicamba of 85 days on filter paper resulting in an analytical deviation. Study authors indicated the deviation had no effect on the study because analysis of the in-swath samples resulted in recoveries within the expected range.

6. The method was not independently validated. A method validation study should be completed from an independent laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

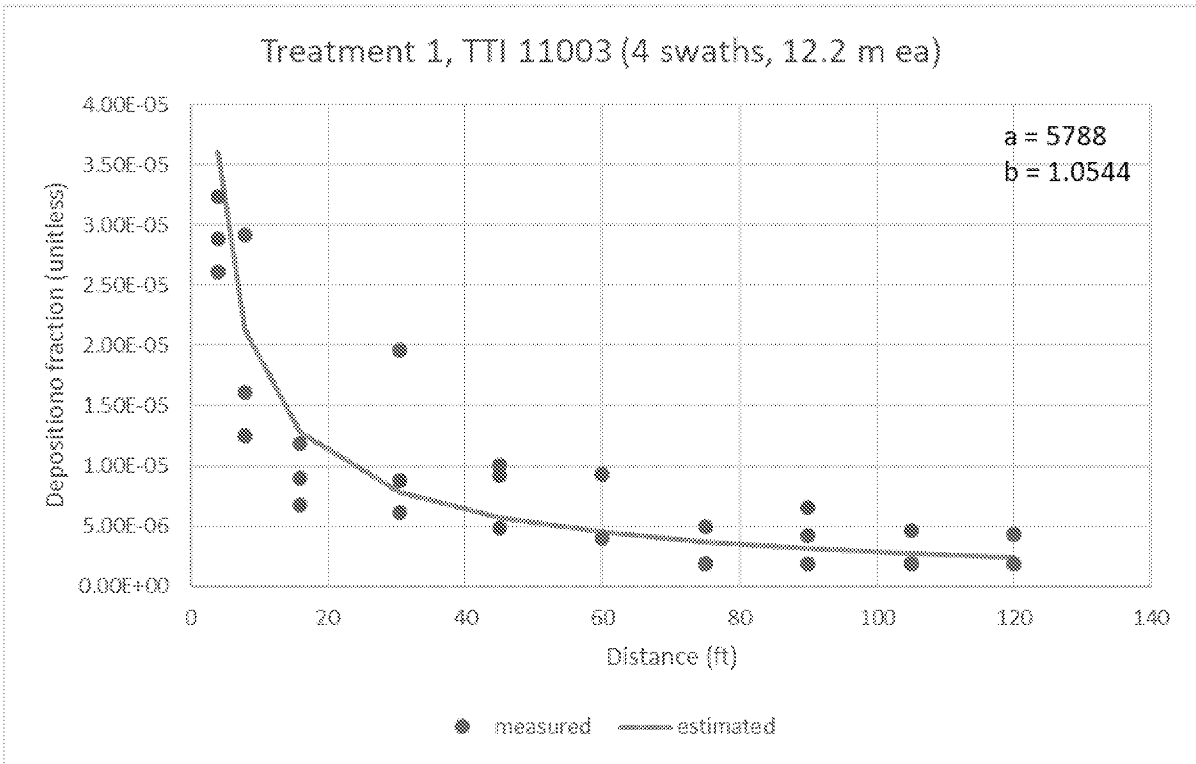
7. The Limit of Detection (LOD) for the analytical method were not reported.

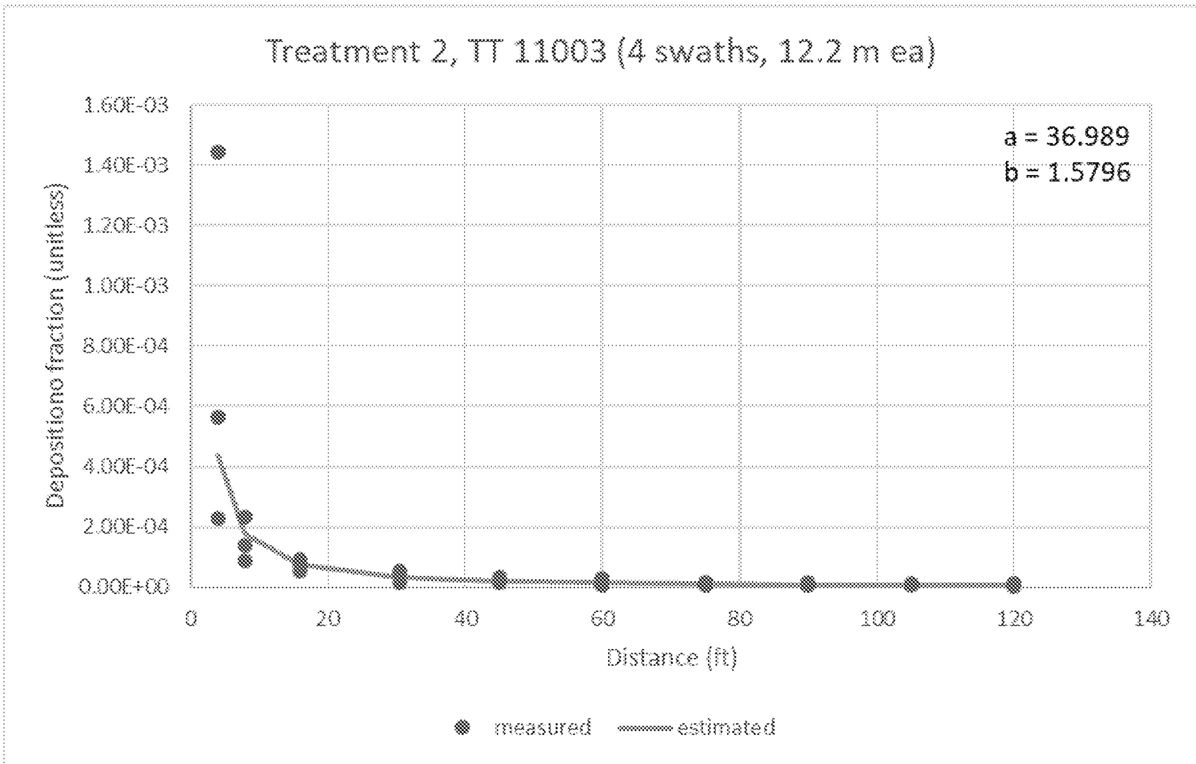
IV. References

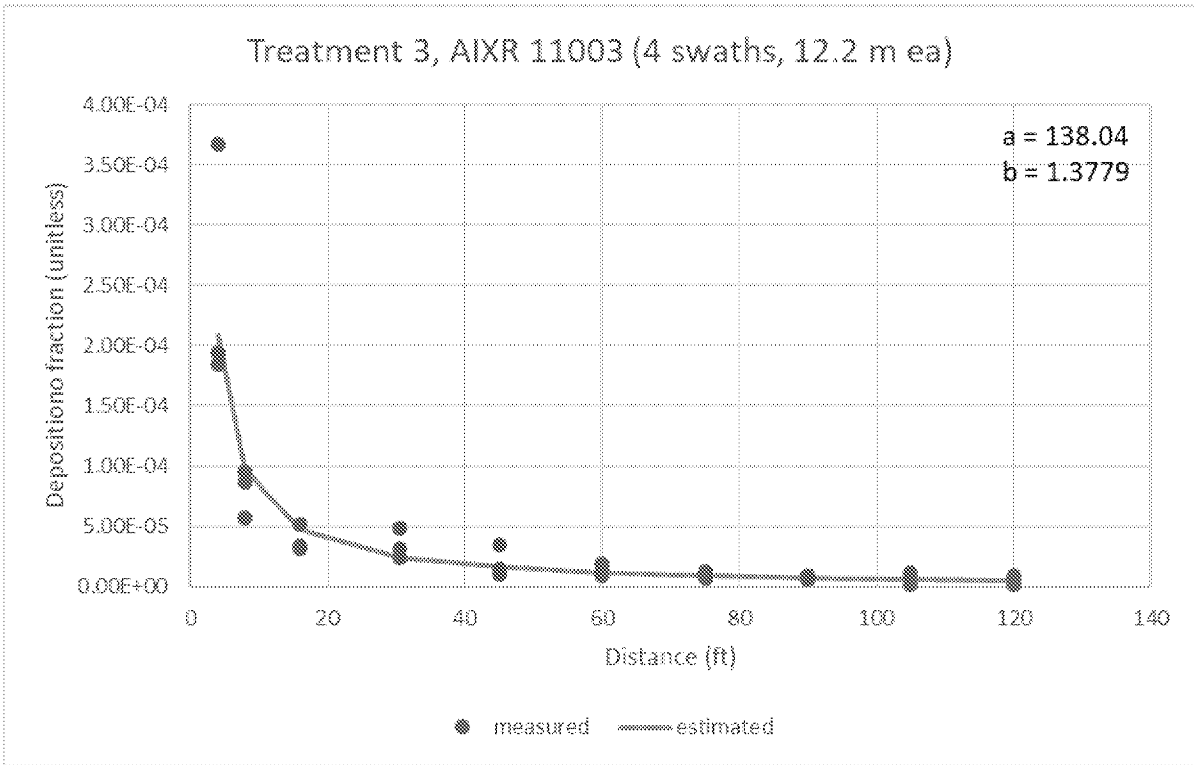
U.S. EPA. (1998). Spray Drift Test Guidelines. OPPTS 840.1200 Spray Drift Field Deposition. United States Environmental Protection Agency, Prevention, Pesticides, and Toxic Substances. EPA 712-C-98-112. March, 1998.

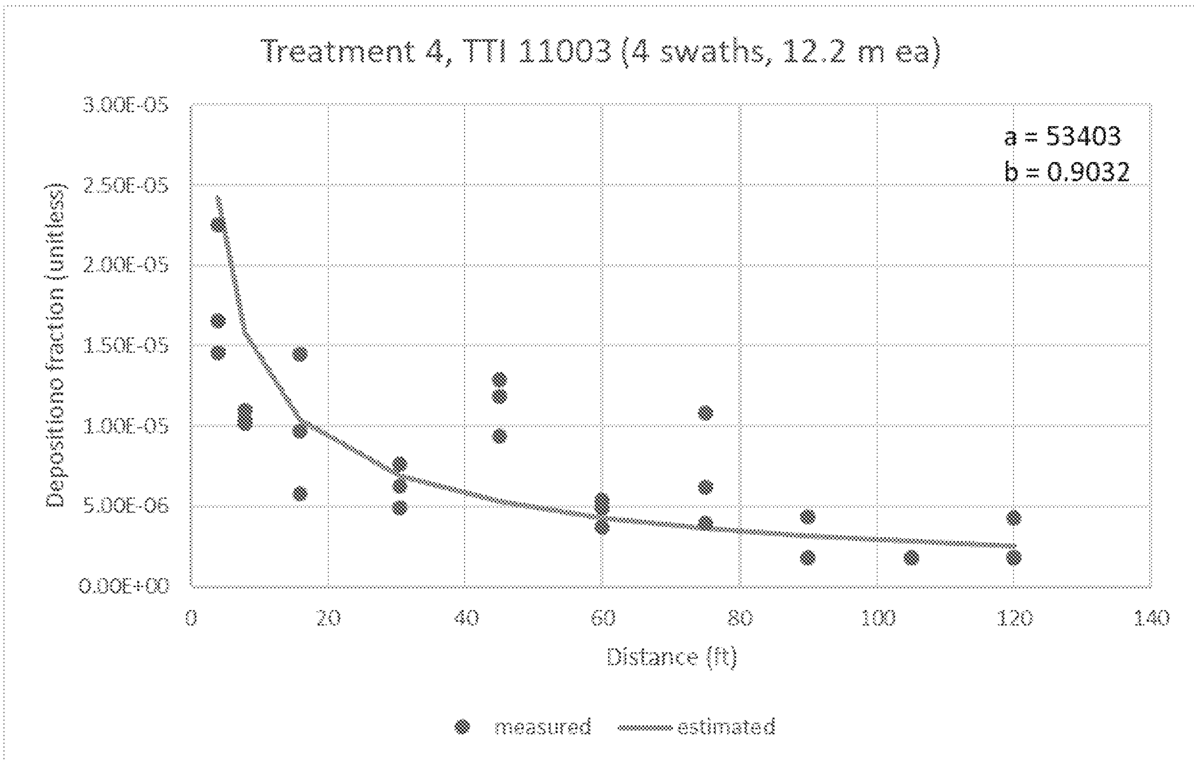
U.S.EPA. (2016). U.S.EPA Generic Verification Protocol for Testing Pesticide Application Spray Drift Reduction Technologies for Row and Field Crops. June 2016

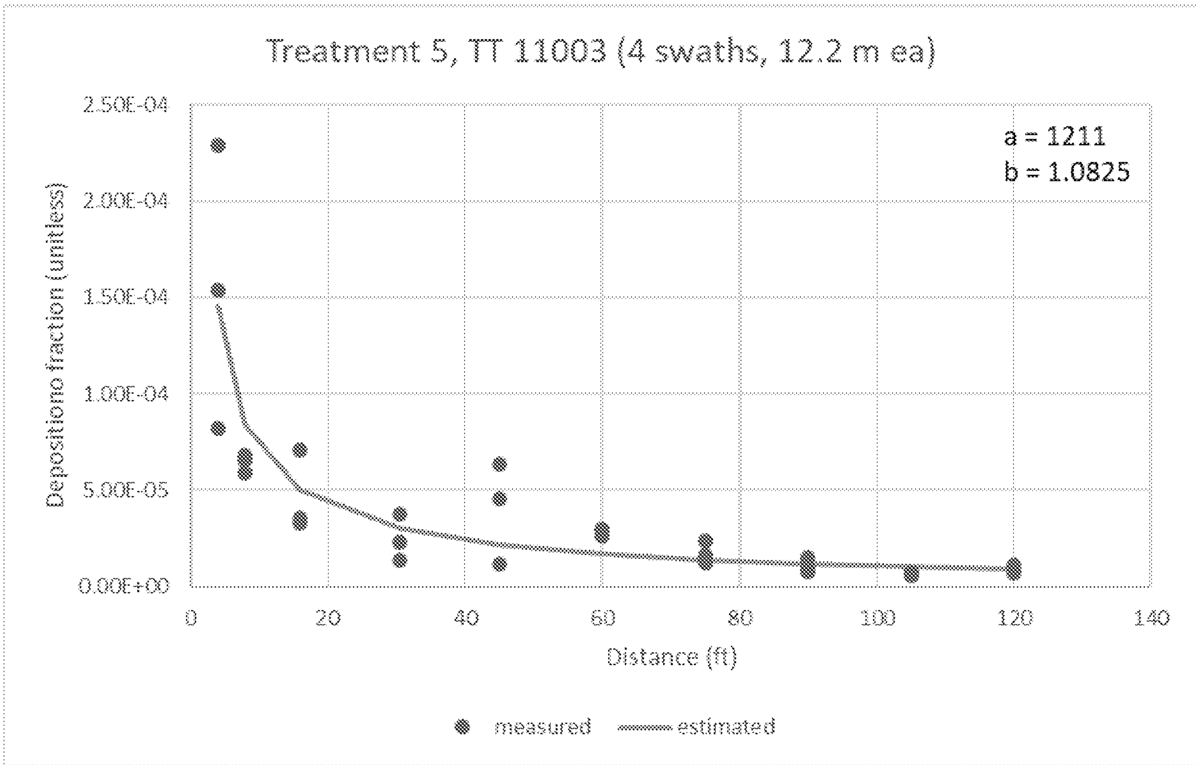
Attachment 1: Reviewer analysis of dicamba drift over distance

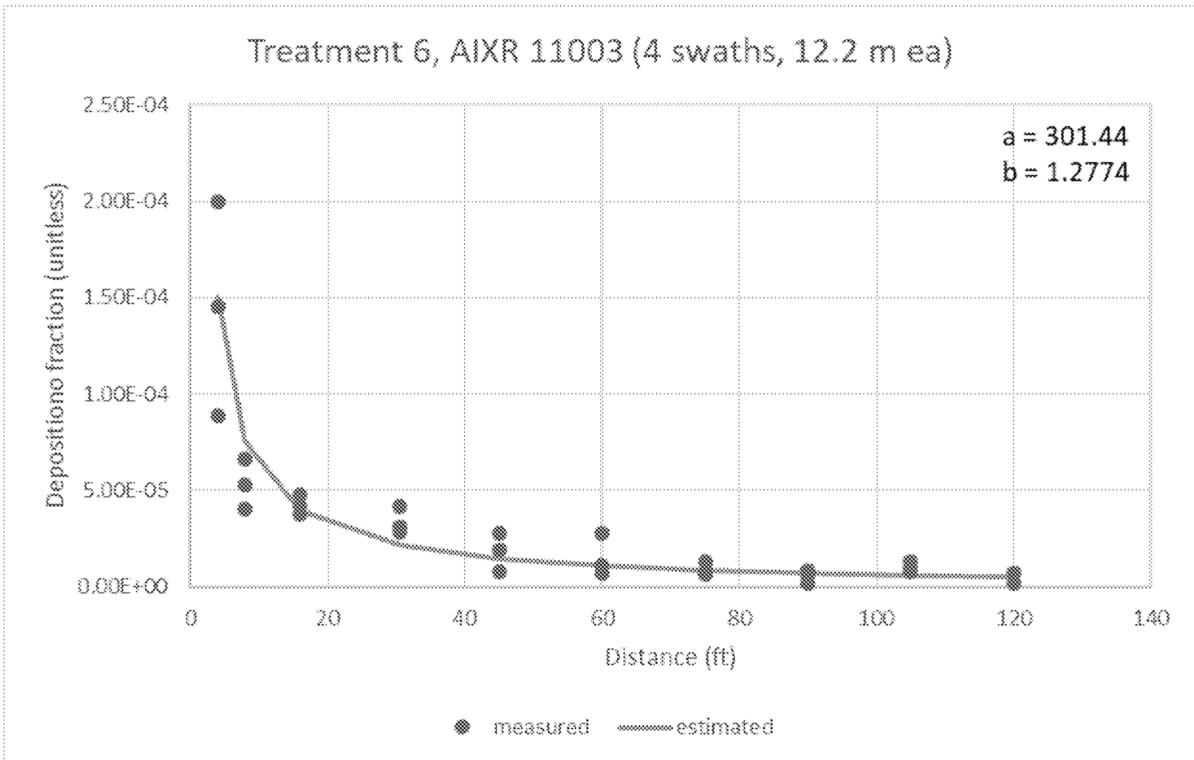


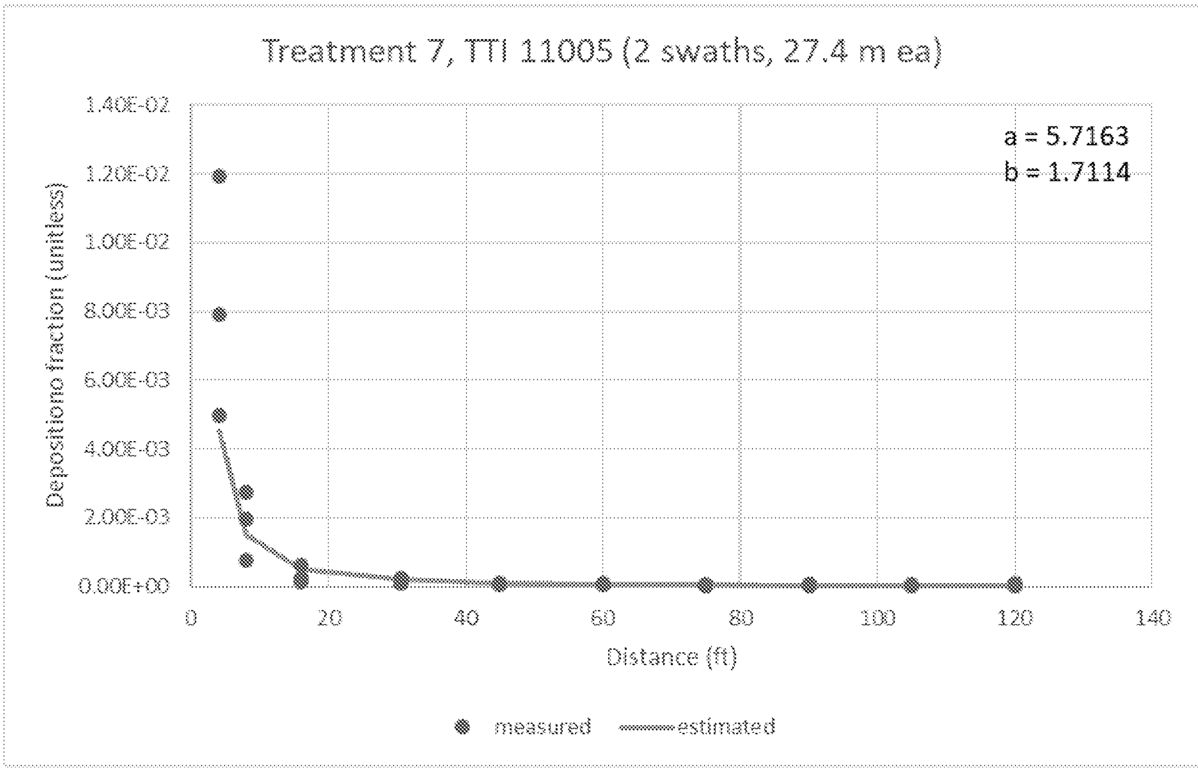


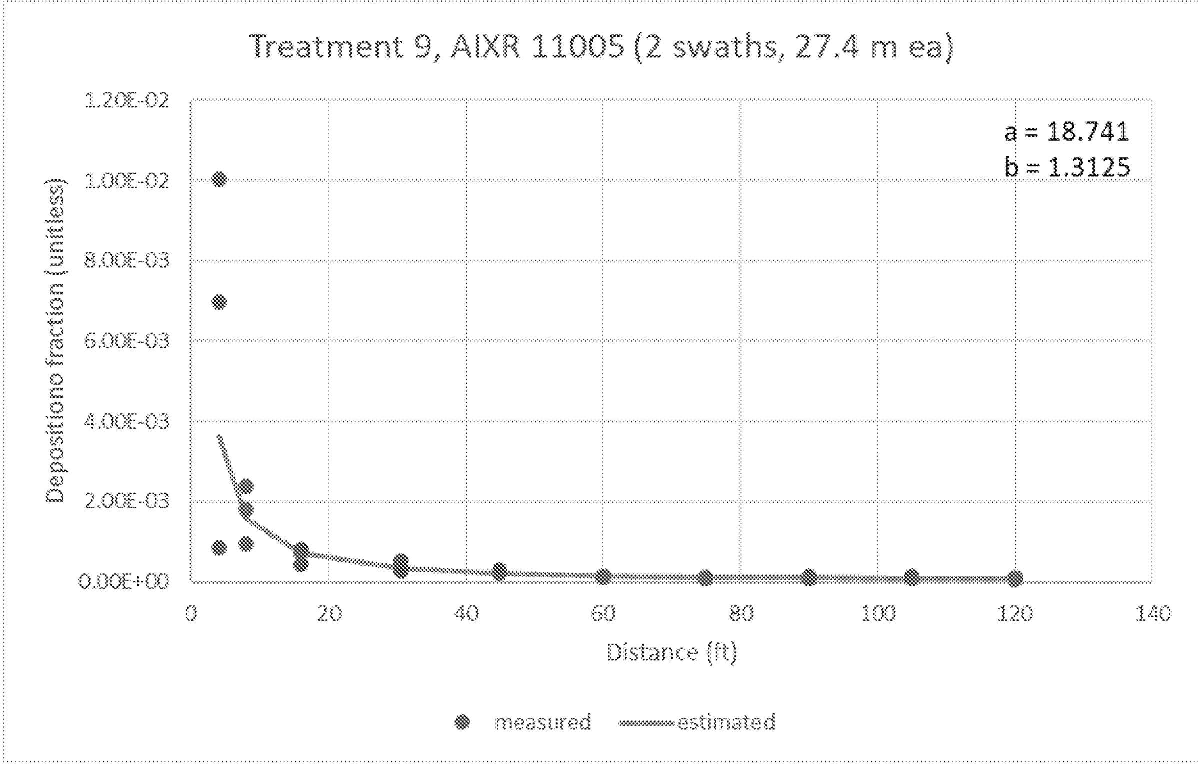

Treatment 3, AIXR 11003 (4 swaths, 12.2 m ea)
a = 138.04
b = 1.3779
Depositiono fraction (unitless)
4.00E-04
3.50E-04
3.00E-04
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

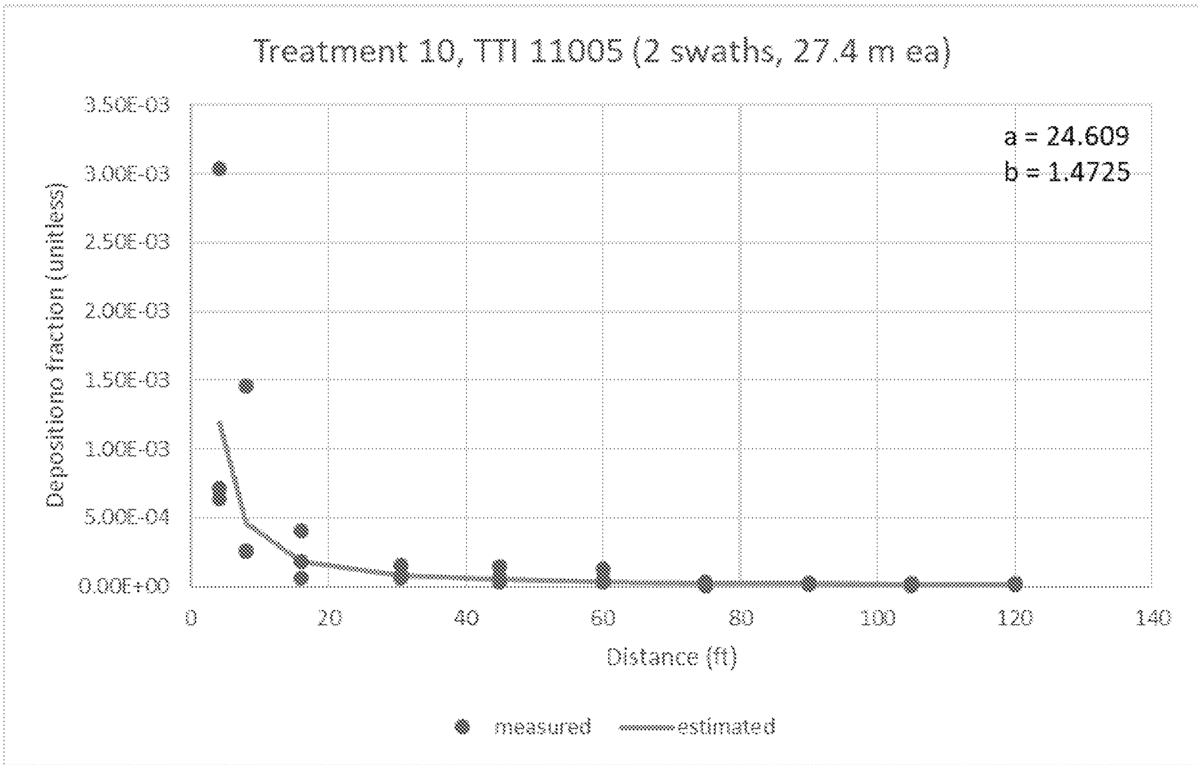

Treatment 4, TTI 11003 (4 swaths, 12.2 m ea)
a = 53403
b = 0.9032
Depositiono fraction (unitless)
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

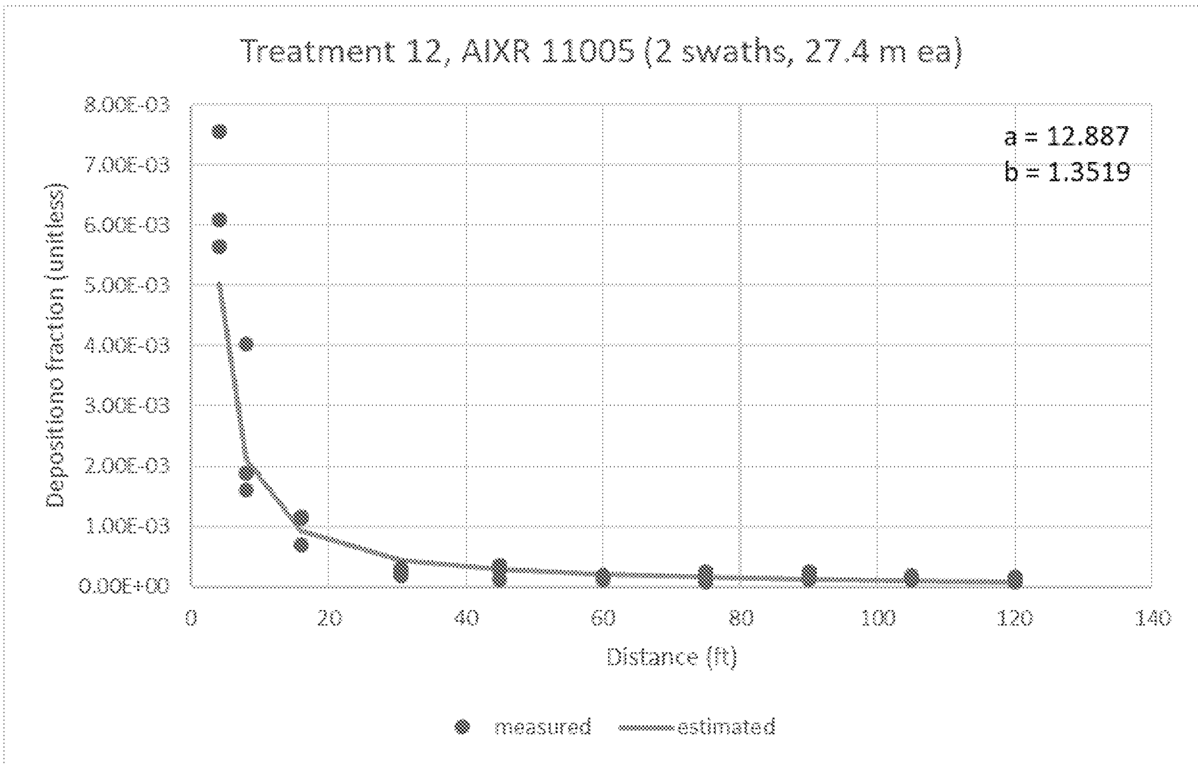

Treatment 5, TT 11003 (4 swaths, 12.2 m ea)
a = 1211
b = 1.0825
Depositiono fraction (unitless)
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

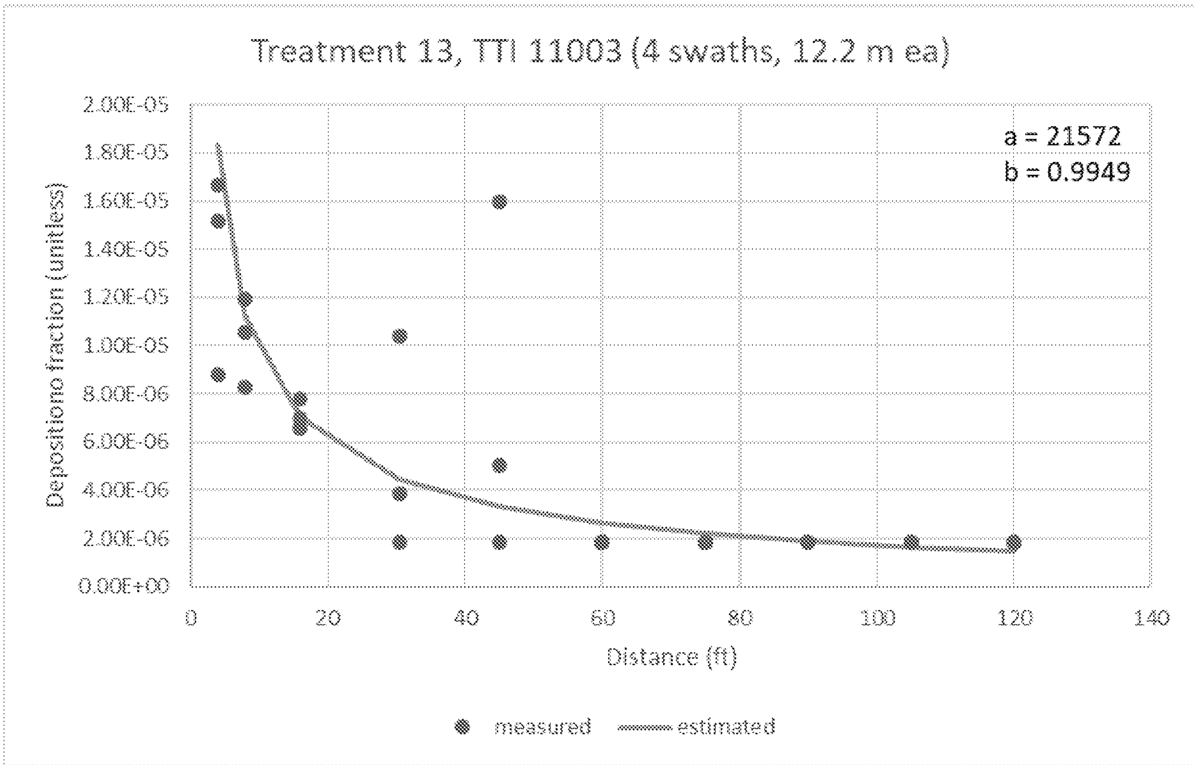

Treatment 6, AIXR 11003 (4 swaths, 12.2 m ea)
a = 301.44
b = 1.2774
Depositiono fraction (unitless)
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

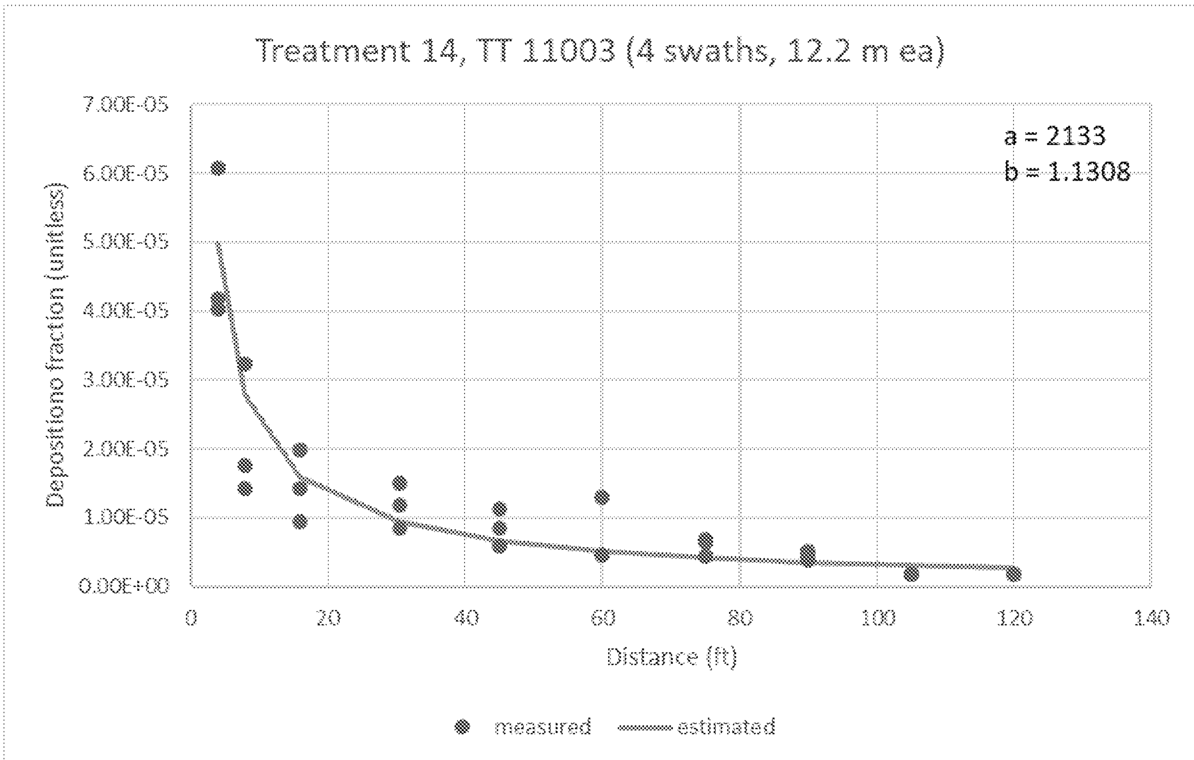

Treatment 7, TTI 11005 (2 swaths, 27.4 m ea)
a = 5.7163
b = 1.7114
Depositiono fraction (unitless)
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

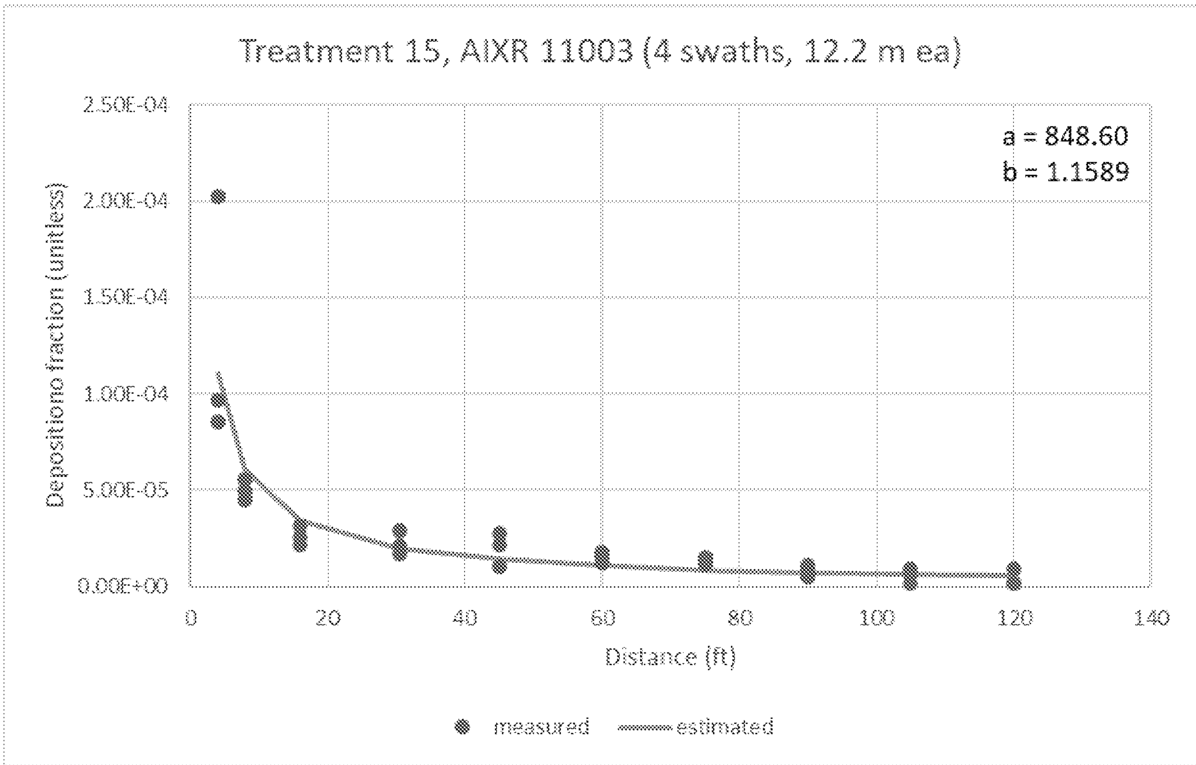

Treatment 9, AIXR 11005 (2 swaths, 27.4 m ea)
a = 18.741
b = 1.3125
Depositiono fraction (unitless)
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

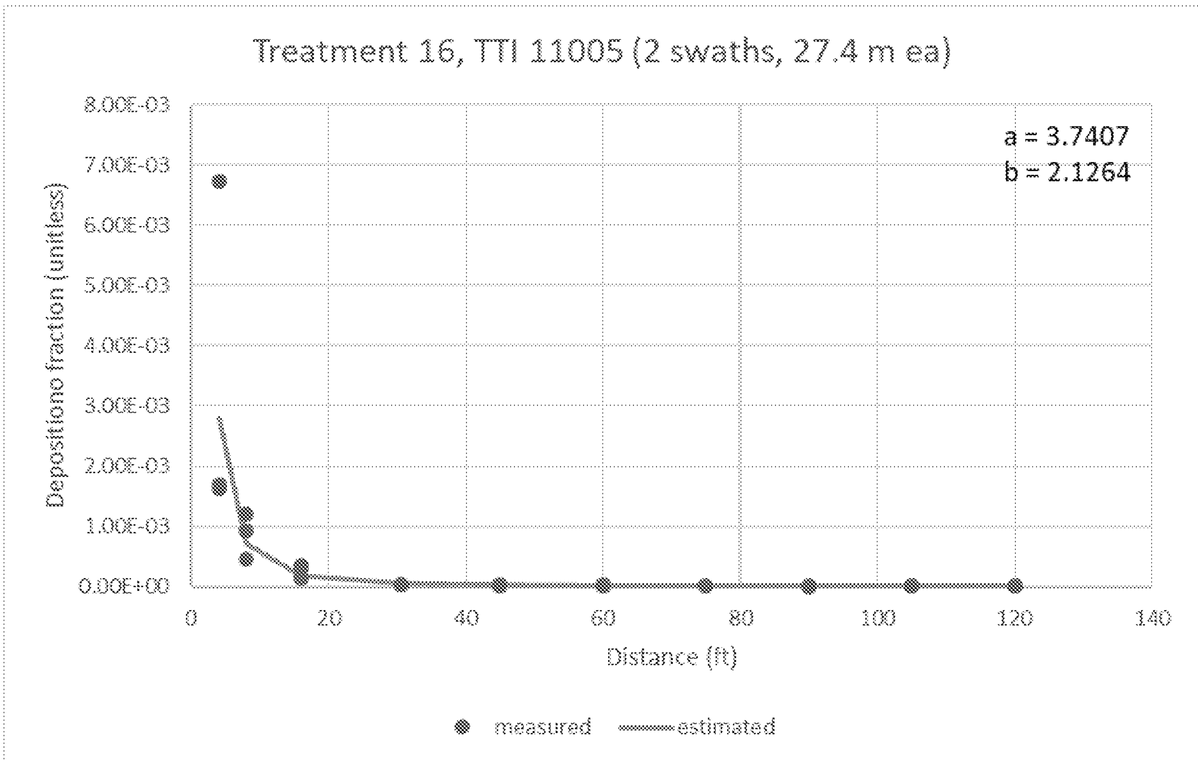

Treatment 10, TTI 11005 (2 swaths, 27.4 m ea)
a = 24.609
b = 1.4725
Depositiono fraction (unitless)
3.50E-03
3.00E-03
2.50E-03
2.00E-03
1.50E-03
1.00E-03
5.00E-04
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

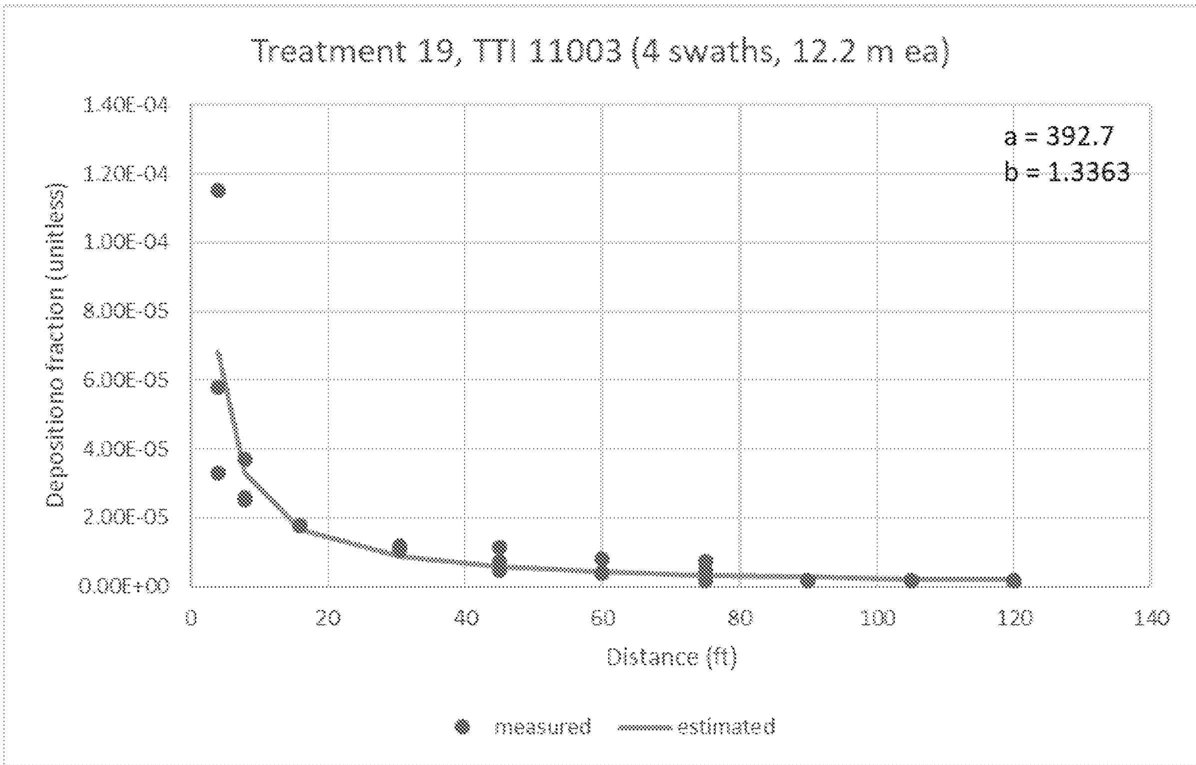

Treatment 12, AIXR 11005 (2 swaths, 27.4 m ea)
a = 12.887
b = 1.3519
Depositiono fraction (unitless)
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

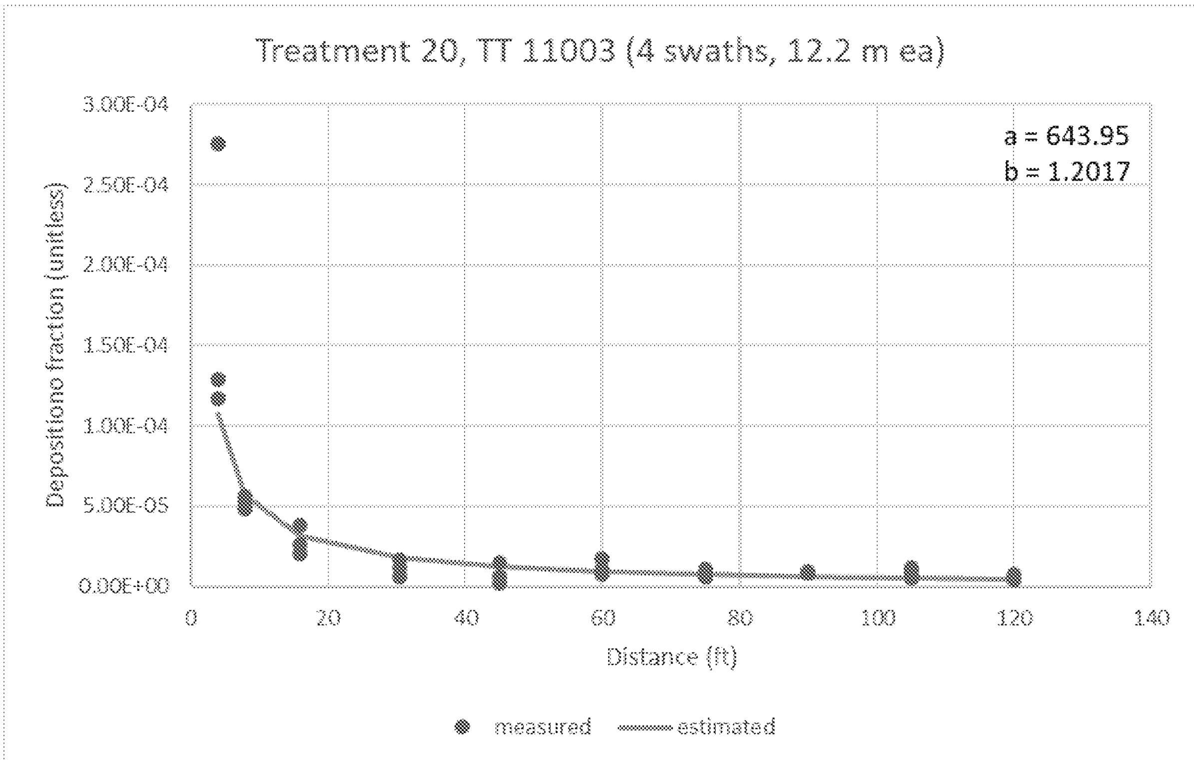

Treatment 13, TTI 11003 (4 swaths, 12.2 m ea)
a = 21572
b = 0.9949
Depositiono fraction (unitless)
2.00E-05
1.80E-05
1.60E-05
1.40E-05
1.20E-05
1.00E-05
8.00E-06
6.00E-06
4.00E-06
2.00E-06
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

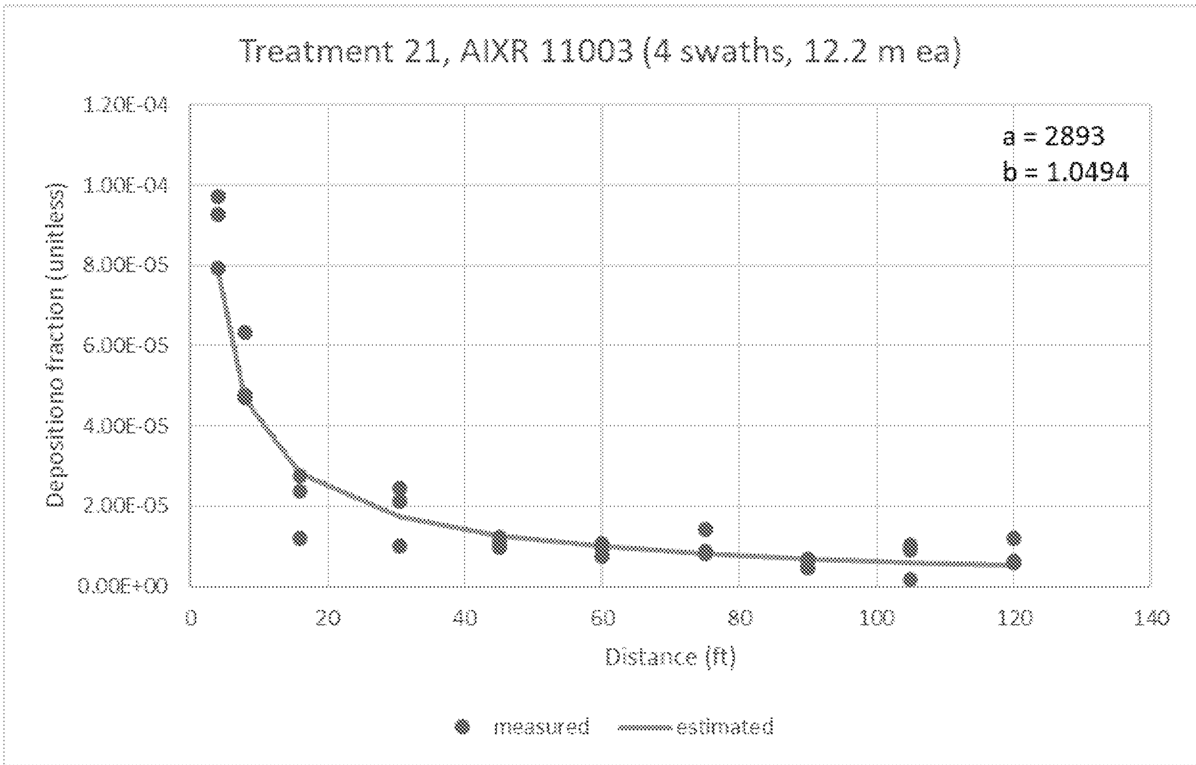

Treatment 14, TT 11003 (4 swaths, 12.2 m ea)
a = 2133
b = 1.1308
Depositiono fraction (unitless)
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

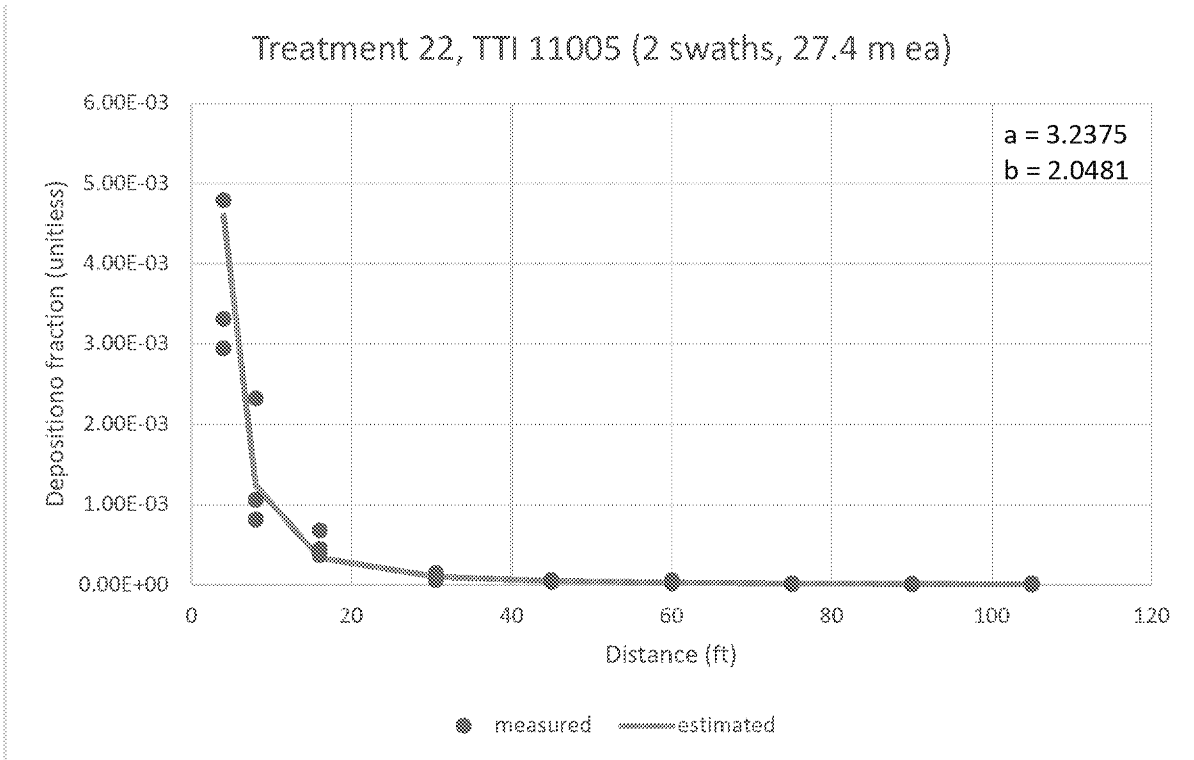

Treatment 15, AIXR 11003 (4 swaths, 12.2 m ea)
a = 848.60
b = 1.1589
Depositiono fraction (unitless)
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

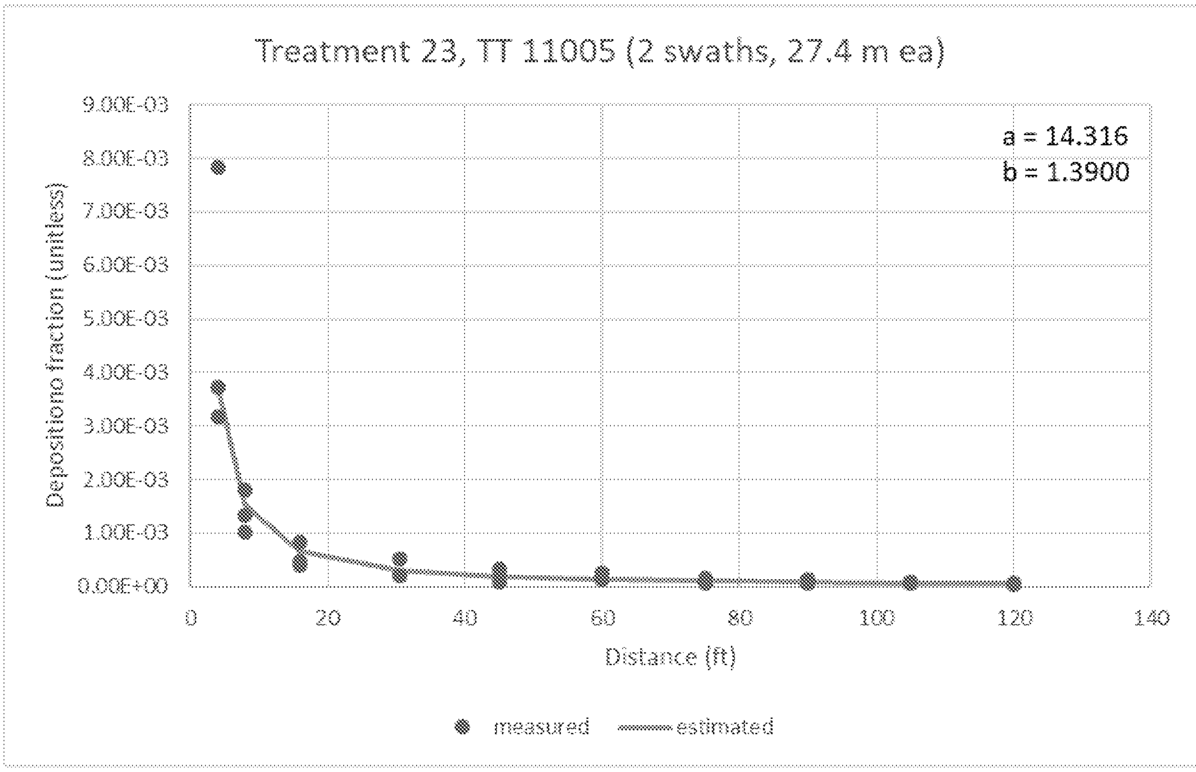

Treatment 16, TTI 11005 (2 swaths, 27.4 m ea)
a = 3.7407
b = 2.1264
Depositiono fraction (unitless)
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

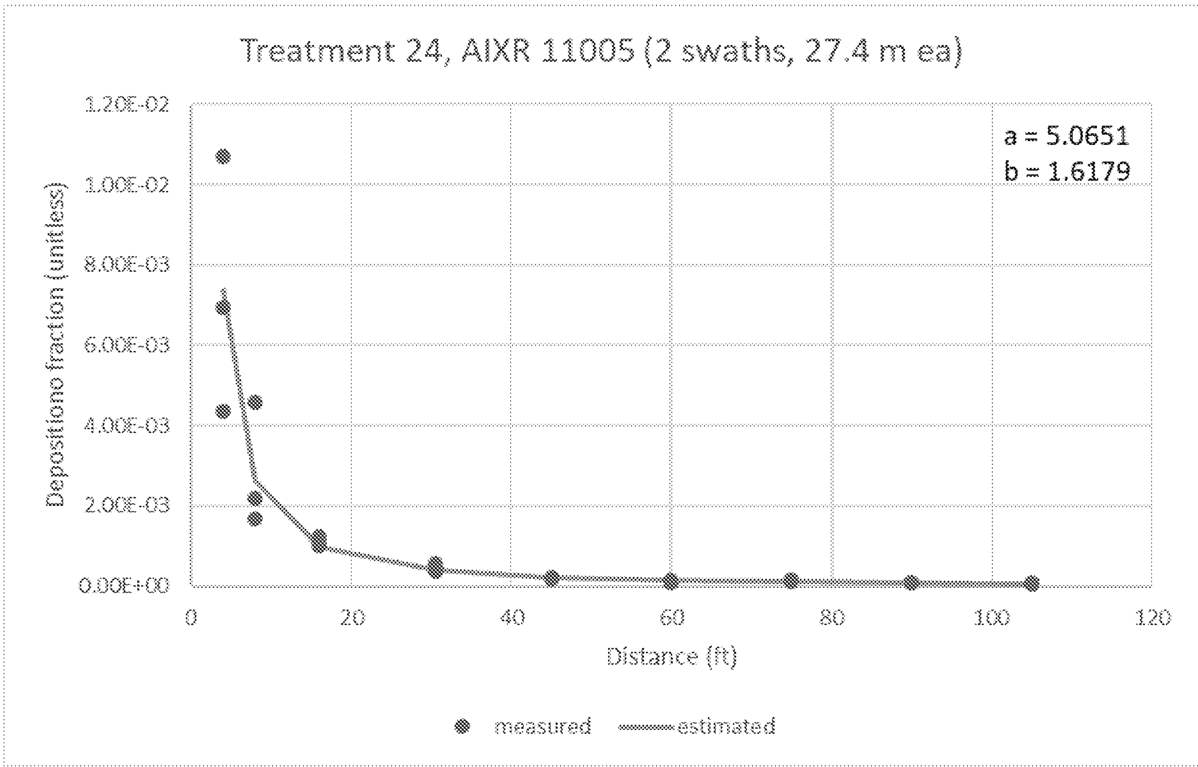

Treatment 19, TTI 11003 (4 swaths, 12.2 m ea)
a = 392.7
b = 1.3363
1.40E-04
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
Depositiono fraction (unitless)
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated


Treatment 20, TT 11003 (4 swaths, 12.2 m ea)
a = 643.95
b = 1.2017
3.00E-04
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
Depositiono fraction (unitless)
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated


Treatment 21, AIXR 11003 (4 swaths, 12.2 m ea)
a = 2893
b = 1.0494
Depositiono fraction (unitless)
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated


Treatment 22, TTI 11005 (2 swaths, 27.4 m ea)
a = 3.2375
b = 2.0481
Depositiono fraction (unitless)
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0
20
40
60
80
100
120
Distance (ft)
measured
estimated


Treatment 23, TT 11005 (2 swaths, 27.4 m ea)
a = 14.316
b = 1.3900
Depositiono fraction (unitless)
9.00E-03
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0
20
40
60
80
100
120
140
Distance (ft)
measured
estimated

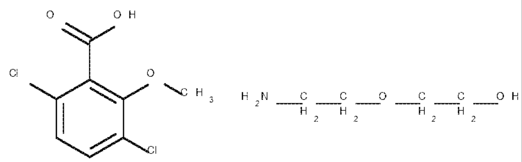

Treatment 24, AIXR 11005 (2 swaths, 27.4 m ea)
a = 5.0651
b = 1.6179
Depositiono fraction (unitless)
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0
20
40
60
80
100
120
Distance (ft)
measured
estimated

ATTACHMENT 2. Supporting Analysis and Spreadsheets.

Supporting analysis and calculations are provided in the attached workbook.

128931_51242201_DE
R-Fate_840.1200_09-2:

ATTACHMENT 3. Dicamba and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
PARENT						
Dicamba-diglycolamine salt of dicamba	IUPAC: 3,6-Dichloro-o-anisic acid-2-(2-aminoethoxy)ethanol CAS: 2-(2-Aminoethoxy)ethanol;3,6-dichloro-2-methoxy-benzoic acid CAS No.: 104040-79-1 Formula: $C_{12}H_{17}Cl_2NO_5$ MW: 326.17 g/mol SMILES: COc1c(Cl)ccc(Cl)c1C(=O)O.NCCOCCO		840.1200 Spray drift	51242201	NA	NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

[A] AR means “applied radioactivity”. MW means “molecular weight”. NA means “not applicable”.